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June 20, 2018

Jason Robinson
Denney & Barrett, P.C.
870 Copperfield Dr.
Norman, OK 73072

RE: Ms. [redacted] [redacted] [redacted]

Dear Mr. Robinson:

Pursuant to your request, I am setting forth my biomechanical opinions regarding the motor vehicle accident on March 17, 2014, involving [redacted] [redacted]. I am also providing a summary of my background and qualifications to render my opinions.

A. <u>BACKGROUND AND EXPERIENCE</u>

- Copy of CV outlining education and experience is attached.
- Professor in College of Engineering, Director of the Impact Biomechanics Laboratory and Director of Automotive Systems Laboratory, North Dakota State University (NDSU).
- Clinical Faculty and Adjunct Professor, Department of Clinical Neuroscience, University of North Dakota (UND) School Of Medicine.
- Involved in research and education in the field of vehicle dynamics and biomechanics for over 35 years.
- Research focus on human body biomechanics for last 25 years.
- Consulted, for past 25 years, in the area of biomechanics, with various governmental agencies including National Highway Traffic Safety Administration (NHTSA), United States Air Force (USAF), United States Army, Department of Defense (DoD), and United States Product Safety Commission (USCPSC).
- Selected to conduct research for USAF at Armstrong Aerospace Research Laboratory (AARL)/Human Systems Division, Wright-Patterson Air Force Base (WPAFB) Dayton, OH, that included laboratory studies of entire human body responses to impact, biodynamic modeling and development of biodynamics injury criteria; and received six (6) research contracts from USAF that involved biomechanical analysis of over 900 full scale laboratory tests with male and female pilots.

EXHIBIT
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- Two (2) most current research contracts (over $1M), supported by DoD have been in area of biomechanical analysis of injury and injury protection for US soldiers returning from combat in Iraq and Afghanistan.
- Involved for several years in Emergency Room (ER) Biomechanical Brain Injury Evaluation Research, with Fargo-Moorhead (FM) Ambulance Service and MeritCare Trauma Center, sponsored, in part, by MeritCare Foundation, Fargo, ND.
- From 2007 to present, invited to chair three (3) scientific peer review committees, as well as serve as a scientific reviewer for numerous other committees for DoD Post Traumatic Stress Disorder/Traumatic Brain Injury (PTSD/TBI) Research Program.
- Current Chairman of North American Brain Injury Society (NABIS).
- Named founding chair of Blast Injury Institute.
- Received additional specialized training with certifications in areas of Abbreviated Injury Scale (AIS) and Crash Data Analysis.
- Professor for over 35 years, of a variety of subjects in the field of engineering including, biomechanics, vehicle dynamics, and dynamics.
- Invited to give many national and international presentations, including ones to governmental agencies such as USCPSC.
- Published four (4) book chapters on brain and neck injury and over one-hundred (100) peer-reviewed publications.
- Fully accredited Accident Reconstructionist, Accreditation Commission for Traffic Accident Reconstruction (ACTAR #1939).

B. <u>OBJECTIVE</u>

Pursuant to your request, I am setting forth my opinions in the areas of vehicle dynamics (accident reconstruction) and human body dynamics (biomechanics) regarding the motor vehicle incident on March 17, 2014, involving Ms. K[redacted] F[redacted]

C. <u>MATERIALS REVIEWED</u>

1. Oklahoma Traffic Collision Report
2. CDR Report – Chevrolet Malibu
3. Munsell Consulting Services Report (Photographs)
4. Medical Records of K[redacted] F[redacted]
   a. EMSA 3/17/14
   b. OU Medical Center 3/17/14 – 3/22/14
   c. OUCP Sooner Pediatric Clinic 3/17/14 – 3/21/14
5. Medical Records of Ashley Faust
   a. Eaglemed
   b. OU Medical Center 3/17/14 – 3/31/14
   c. OU Physicians
   d. OU Medical Center 4/7/14 – 8/10/15
   e. OU Physicians Orthopedic
   f. Dean McGee Eye Institute
   g. OU Medical Center 8/15/15 – 8/8/15
   h. OU Medical Center 11/23/15 – 9/23/16
   i. OU Medical Center 4/29/16 – 5/1/16
   j. OU Medical Center 5/10/16
   k. OU Medical Center 7/28/16 – 7/29/16
   l. University Oral & Maxillofacial Surgery
   m. OU College of Dentistry

6. Deposition and Exhibits of Ashley Faust
7. Deposition and Exhibits of Elizabeth Kiihr
8. Deposition and Exhibits of David Prentkowski
9. Deposition and Exhibits of Hamed Sadrnia
10. Report of Mr. Neil Hannemann, Automotive Engineer
11. Photographs

D. <u>TASKS PERFORMED</u>

For this analysis, I have done the following:

1. Studied the provided materials.
2. Determined vehicle parameters for the 2012 Chevrolet Malibu.
3. Inspection of the subject vehicle on June 4, 2018.
4. Assessed the impact phase of vehicle dynamics.
5. Determined K[redacted] F[redacted]'s segments' geometric and mass properties, and the joints' locations and range of motion characteristics using the Generator of Body Data (GEBOD) AL/WPAFB computer program.
6. Performed K[redacted] F[redacted]'s body dynamics analysis for selected phases of the event.
7. Performed 3D Faro Laser Scans of the 2012 Chevrolet Malibu.
8. Performed 3D Faro Laser Scans of the incident scene.

E. <u>ANALYSIS:</u>

E-1 <u>General Concept</u>

The area of biomechanics is a component of bioengineering. The biomechanical analysis is based on the principles of physics, engineering including viscoelastic properties of tissue, as well as life sciences. Impact biomechanics is the study of damage (failure) of human body regions, organs, tissue or cells as a result of the sudden application of forces. The concept of damage/failure can be structural or physiological which, in a clinical setting, is referred to as "injury" or "trauma".

One of the common objectives for a biomechanical analysis is to determine whether the injury mechanism for damage (failure) was present and whether or not the forces were sufficient to cause the damage. Biomechanical engineers do not perform clinical diagnoses. They accept the diagnoses as presented in the medical records.

The procedure for biomechanical analysis (Figure 1) involves an understanding of the driving force that can be quantified in terms of generally accepted engineering parameters like change in the velocity, time duration of impact, and/or vehicle acceleration (VEHICLE DYNAMICS ANALYSIS). The quantification of impact severity from occupant perspective is the remaining portion of the biomechanical evaluation (HUMAN BODY DYNAMICS ANALYSIS). The meaning of the results from the biomechanical analysis is illustrated by comparison against human tolerances (HUMAN TOLERANCE ANALYSIS).

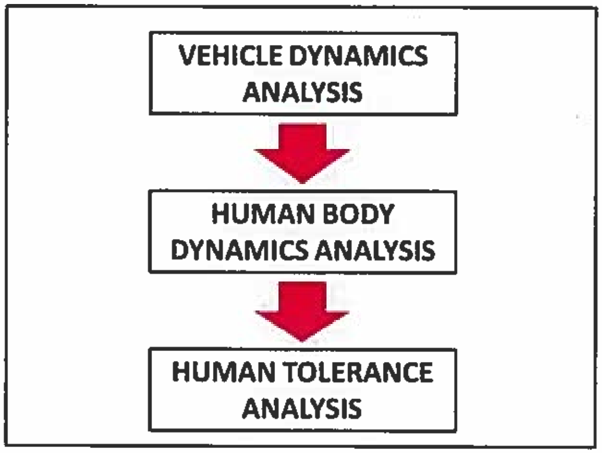

Figure 1 – Complete Procedure for Biomechanical Analysis

E-2 <u>Accident Description</u>

According to the narrative opinion given in the Official Oklahoma Traffic Collision Report:

> *"Unit 1 was traveling in a north east direction on Jones Spencer Road. Unit 1 driver crossed the center line and was driving in the south west lane. Unit 1 continued in the north east direction right of the center line. Unit 1 departed the roadway and collided with a tree. At this time it is not clear why the driver departed the roadway."*

The accident diagram from the Collision Report is shown in Figure 2 (color and labels added). The Google Earth (overview) location of the incident was determined based on highway names and distance measurements given in the crash report (Figure 3). Figure 4 is select photos taken at the scene on the day of the incident. Figure 5 shows the area of the incident as seen at street level. Select 3D Faro scans of the incident location are shown in Figure 6.

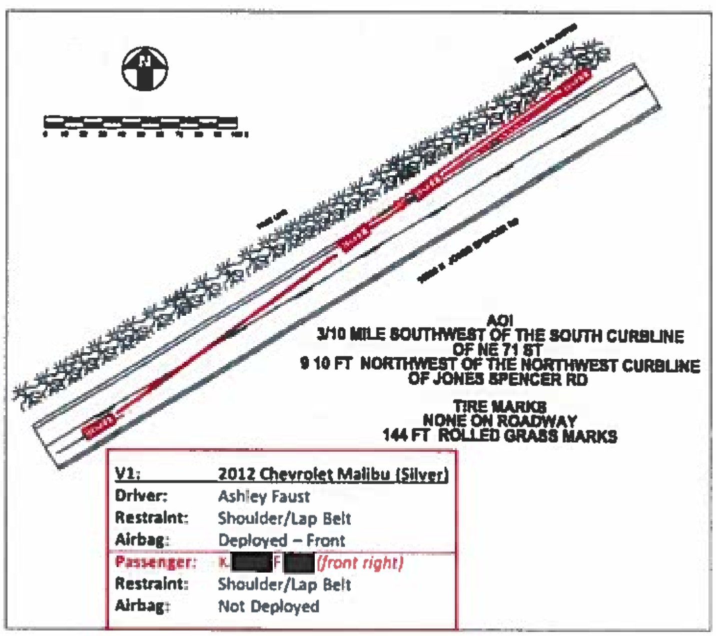

Figure 2 – 1st Incident Accident Diagram (Color and Labels Added)

Figure 3 – Google Earth Image (Overview)

Figure 4 – Select Photos Taken at the Scene

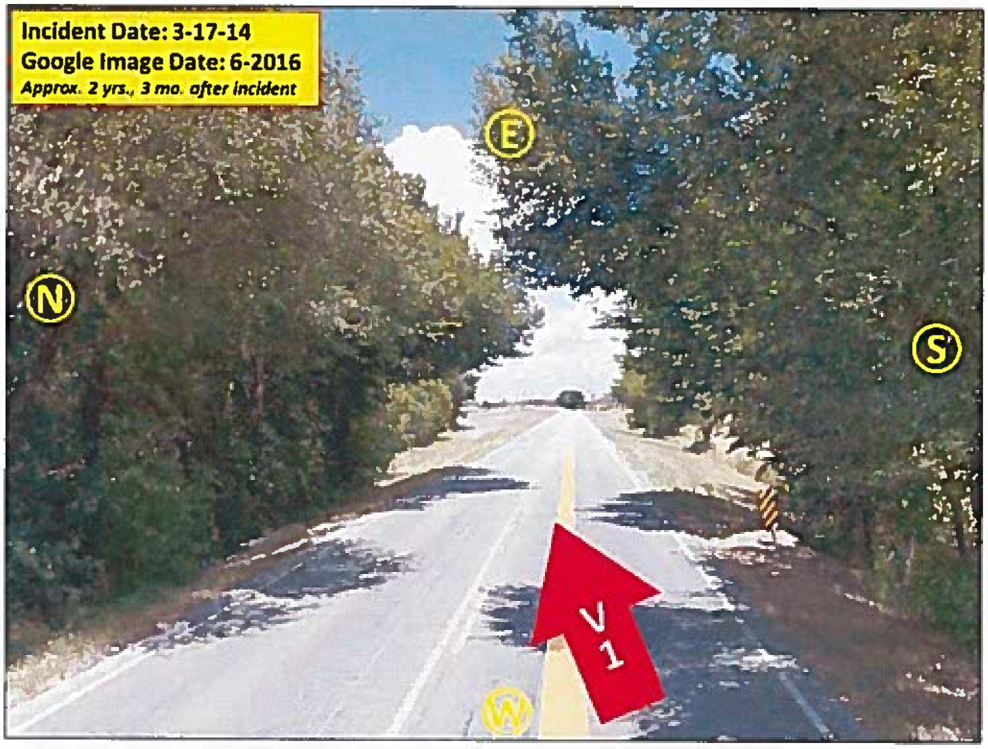

Figure 5 – Google Earth Image (Street View)

Figure 6 – Select 3D Faro Scans of Incident Location

E-3 Vehicle Damage Analysis

My inspection of the subject Chevrolet Malibu vehicle revealed extensive damage consistent with a frontal offset impact with a tree. From a trauma biomechanics perspective, in this case, the most relevant areas of damage included but were not limited to, the front bumper area and hood of the vehicle. Based on the nature and extent of the Chevrolet Malibu's damage, it is obvious the structural components were subjected to compressive forces exhibited by dynamic progressive buckling characteristics. The subject of

dynamic progressive buckling has been extensively studied. There is a broad base of peer-reviewed publications. For example:

McNay, G. H. II, "Numerical Modeling of Tube Crush with Experimental Comparison", Society of Automotive Engineers #8808

Mahmood, H. F., et al, "Design of Thin Walled Columns for Crash Energy Management – Their Strength and Mode of Collapse", Society of Automotive Engineers #811302

Mahmood, H.F. et al, "Crash Analysis of Thin Walled Beam-Type Structures", Society of Automotive Engineers #880894

Schmueser, D. W., et al, "Front Impact of Primary Structural Components of a Composite Space Frame", Society of Automotive Engineers #88090

Tundermann, J. H. Et al, "The Application of Elastometric Buckling Columns in an Energy Management Bumper System", Society to Automotive Engineers #750011

Selected references from the research work that I was personally involved in are:

***Ziejewski, M.,** B. Anderson, M. Rao and M. Hussain, "Energy Absorption for Short Duration Impacts", SAE Paper #961851, Indianapolis, IN 1996*

***Ziejewski, M.,** B. Anderson, "The Effect of Structural Stiffness on Occupant Response for A –Gx Acceleration Impact", SAE Paper #962374, Sao Paulo, Sp, Brazil, 1996*

***Ziejewski, M,** H. Goettler, "Effect of Structural Stiffness and Kinetic Energy on Impact Force", SAE Paper #961852, Indianapolis, IN, 1996*

*Anderson, B., **M. Ziejewski**, H. Goettler, "Method to Predict the Energy Absorption Rate Characteristics for a Structural Member", SAE Paper #982388, Detroit, MI, 1998*

*Pan, X., **M. Ziejewski**, H. Goettler, "Force Response Characteristics of Square Columns for Selected Materials at Impact Loading Combinations Based on FEA", SAE #982418, Detroit, MI, 1998*

The damage assessment for the Chevrolet Malibu was carried out using two different approaches: laser-based measurements and basic measuring tools. Selected images from the 3D FARO Laser System and photographs taken during my inspection are shown in Figures 7 and 8.

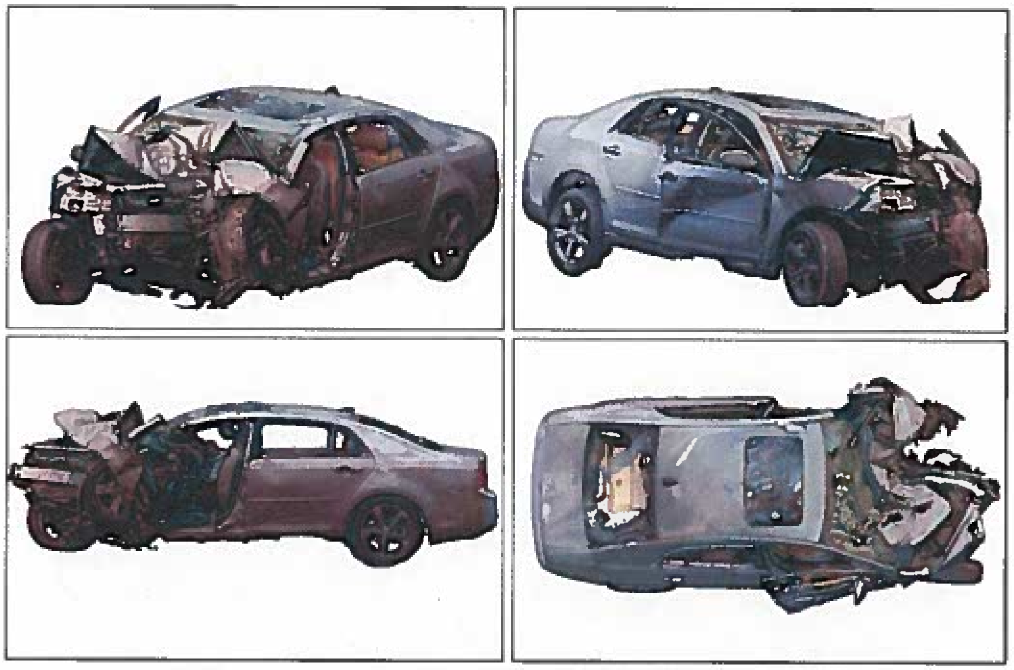

Figure 7 – 3D FARO Laser Image for the 2012 Chevrolet Malibu

Figure 8 – Selected Photos of 2012 Chevrolet Malibu

The photogrammetry technique is based on the principle of technical drawing, geometric constructions, and drawing perspectives. Photogrammetry is well known and recognized in engineering in general and in accident reconstruction including determination of the vehicle deformations. Part of the photogrammetry process involves superimposing the undeformed vehicle with a scale that will overlay the photograph depicting the deformed vehicle. Photogrammetry is based on fundamental principles known since 30 B.C.

The textbook "Technical Drawing" was, for many years, the choice textbook for many engineering colleges throughout the United States. I personally taught from this textbook for many years as well. It states, "This method utilizes actual photographs of the earth's surface and of man-made objects on the earth....it is issued for such activities as governmental and commercial surveying...It has the great advantage of being easy to use....". "...it is possible not only to determine the relative positions of objects in a horizontal plane, but it is also possible to determine relative elevations." Photogrammetry is also widely accepted in the Automotive Engineering Community. Peer-reviewed articles are:

Kerkhoff, John F., "Photographic Technique for Accident Reconstruction", Society of Automotive Engineers #850248, 1985

Gillen, Larry, "Photogrammetric Mapping of Vehicle Deformations", Society of Automotive Engineers #861421, 1986

This method is widely accepted in the traffic accident investigation field. In "The Traffic Accident Investigation Manual – At Scene Investigation and Technical Follow-Up" topic 830 is titled "Photogrammetry for Traffic-Accident Investigation." There is also an example from the Accident Reconstruction Journal informing the readers about computerized photogrammetry techniques for assessment of vehicle damage.

Baker, J. S. and L. Fricke, The Traffic-Accident Investigation Manual, Topic 830, "Photogrammetry for Traffic-Accident Investigations", 30-1 to 30-29, Ninth Edition, 1985

Rohde, R., "An Introduction to Desktop Photogrammetry", Accident Investigation Quarterly, Summer, 1995, pp.16-23

The more current photogrammetry techniques I utilized are described and validated in the following SAE publications.

Neal, W.T.., et al, "Photogrammetric Measurement Error Associated with Lens Distortion", Society of Automotive Engineers #2011-01-0286, 2011

Rose, N.A., et al, "A Method to Quantify Vehicle Dynamics and Deformation for Vehicle Rollover Tests Using Camera-Matching Video Analysis", Society of Automotive Engineers #2008-01-0350, 2008

Rucoba, R., et al, "A Three Dimensional Crush Measurement Methodology Using Two-Dimensional Photographs", Society of Automotive Engineers #2008-01-0163, 2008

Chou, C., et al, "Image Analysis of Rollover Crash Test Using Photogrammetry", Society of Automotive Engineers #2006-01-0723, 2006

Brach, R.M., et al, "Vehicle Accident Analysis and Reconstruction Methods, Chapter 10: Photogrammetry", Society of Automotive Engineers, 2005

Neale, W. T. C., et al, "A Video Tracking Photogrammetry Technique to Survey Roadways for Accident Reconstruction", Society of Automotive Engineers #2004-01-1221, 2004

Fenton, S., et al, "Determining Crash Data Using Camera Matching Photogrammetric Technique", Society of Automotive Engineers 2001-01-3313, 2001

Pepe, M.D., et al, "Accuracy of Three-Dimensional Photogrammetry as Established by Controlled Field Tests", Society of Automotive Engineers #930662, 1993

Husher, S.E., et al, "Survey of Photogrammetric Methodologies for Accident Reconstruction", Proceedings of the Canadian Multi-Disciplinary Road Safety Conference VII, Vancouver, BC, Canada, June 1991

Breen, K.C. and C. E. Anderson, "The Application of Photogrammetry to Accident Reconstruction", Society of Automotive Engineers #861422, 1986

Photogrammetry error rate in vehicle damage mapping is well within 5% and will depend only on the ability of the person being able to read the ruler accurately.

E-3.1 Vehicle Kinematics

According to the Crash Data Retrieval (CDR) report, the following information was noted:

1. Cruise control was not in use.
2. Driver and Passenger's Belt Switch Circuit Status is listed as "BUCKLED".
a) Driver's front airbag deployed.
3. Passenger's front airbag was listed as "Suppressed".
4. One second (-1 s) prior to the impact.
    a) Vehicle speed was recorded as 53 mph.
    b) Antilock Brake System Active – "Yes".
    c) Lateral Acceleration = 4.92 ft/s.
    d) Yaw rate = 14 degrees/s.
    e) Steering wheel input was 224° clockwise.

A compilation of vehicle kinematic parameters based on the CDR is shown in Table 1.

Time (s)	Long. Velocity (mph)	Lat. Velocity (mph)	Res. Velocity (mph)	Average Accel (g)	PDOF (Deg)
-0.07	0.00	0.00	0.00	-	-
-0.06	0.00	0.00	0.00	-	-
-0.05	0.00	0.00	0.00	-	-
-0.04	0.00	0.00	0.00	-	-
-0.03	1.36	0.00	1.36	6.19	0.00
-0.02	4.74	0.68	4.79	15.61	-8.25
-0.01	7.45	2.03	7.72	13.35	-15.82
0.00	15.59	4.07	16.11	38.20	-15.14
0.01	22.36	8.13	23.79	34.96	-21.33
0.02	29.82	9.49	31.29	34.15	-18.57
0.03	37.27	9.49	38.46	32.62	-14.76
0.04	44.05	9.49	45.06	30.05	-12.45
0.05	49.47	10.84	50.64	25.42	-12.66
0.06	54.89	12.20	56.23	25.43	-12.85
0.07	58.96	12.88	60.35	18.76	-12.62
0.08	60.99	11.52	62.07	7.82	-10.89
0.09	62.35	11.52	63.41	6.09	-10.65
0.1	63.70	11.52	64.73	6.05	-10.42
0.11	65.06	12.20	66.19	6.65	-10.81
0.12	65.74	12.20	66.86	3.04	-10.70
0.13	65.74	12.20	66.86	0.00	-10.70
0.14	65.74	12.20	66.86	0.00	-10.70

Table 1 – Vehicle Kinematic Parameters Based on CDR Data

The Principle Direction of Forces (PDOF) of -10 degrees (10 degrees to the left) is shown in Figure 9.

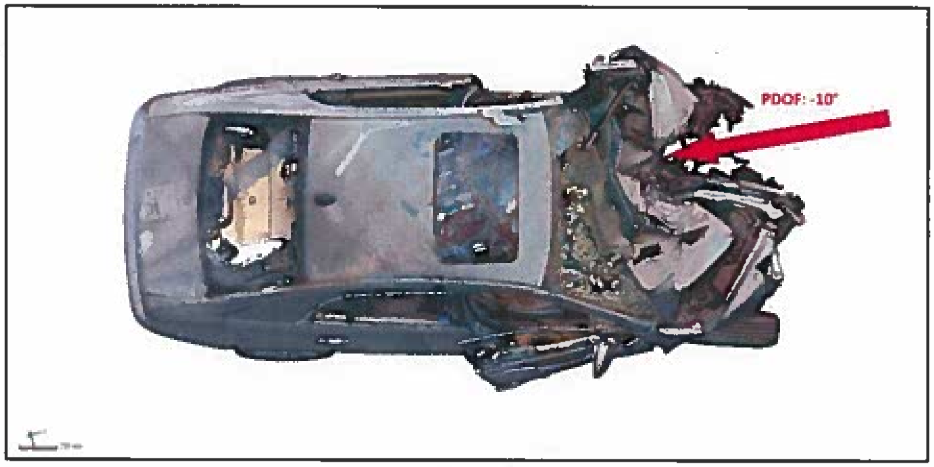

Figure 9 - Principal Direction of Force

To confirm the results from the CDR data, a damage based analysis was completed. The impact analysis was performed based on the damage and using the Engineering Dynamics Corporation EDCRASH computer program. The EDCRASH computer program is a spin-off of the CRASH3 computer program, which is the latest version of the Calspan Reconstruction of Collision Speeds on the Highway (CRASH) computer program from the National Highway Traffic Safety Administration (NHTSA). As its name implies, the CRASH program is a general-purpose computer program, which can be used to estimate vehicle speeds in real-world collisions based on physical evidence obtained by a collision investigator. The objective of these vehicle dynamics programs is to provide a standardized and objective means of interpreting the physical evidence from the scene of an automobile collision and to provide users with a consistent and rationally derived estimate of the velocity changes, pre-impact speeds, and energy dissipated in motor vehicle impacts. The output of the EDCRASH confirms the results of the CDR.

E-4 <u>Human Body Dynamics</u>

Human body dynamics analysis requires a thorough understanding of the complex interaction between different parameters including but not limited to change in velocity (Delta-V), direction and duration of impact, gender, height, weight, body position and others. For several decades many research publications have addressed the complexity of the response of visco-elastic nature of the human body under a variety of loading conditions. As a part of my research work at the Armstrong Aerospace Research Laboratory at Wright Patterson Air Force Base, I have been personally involved in the analysis of more than nine hundred (900) tests with male and female pilots under different loading conditions.

In Ms. [redacted]'s case, I performed an analysis using engineering principles and methodologies generally accepted in the scientific community. Example references are listed below:

Hibbeler, R.C., "Engineering Mechanics – Dynamics", Twelfth Edition, Pearson Prentice Hall, Pearson Education, Inc. 2010

Nahum, A., Gomez M., "Injury Reconstruction: The Biomechanical Analysis of Accidental Injury", Society of Automotive Engineers, #940568.

Robbins, D.H., et al, "Biomechanical Accident Investigation Methodology Using Analytic Techniques", Society of Automotive Engineers, #831609.

The overall (resultant) forces/accelerations acting on different body parts are the cumulative effect of forces along and about the three axes. A graphical illustration of the six force components in three directions is presented in the Figures 10 and 11.

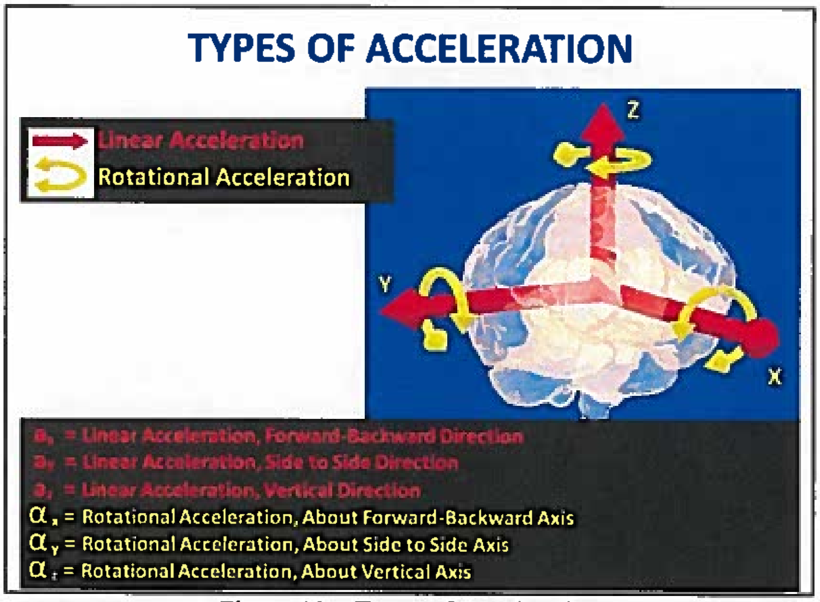

Figure 10 – Types of Acceleration

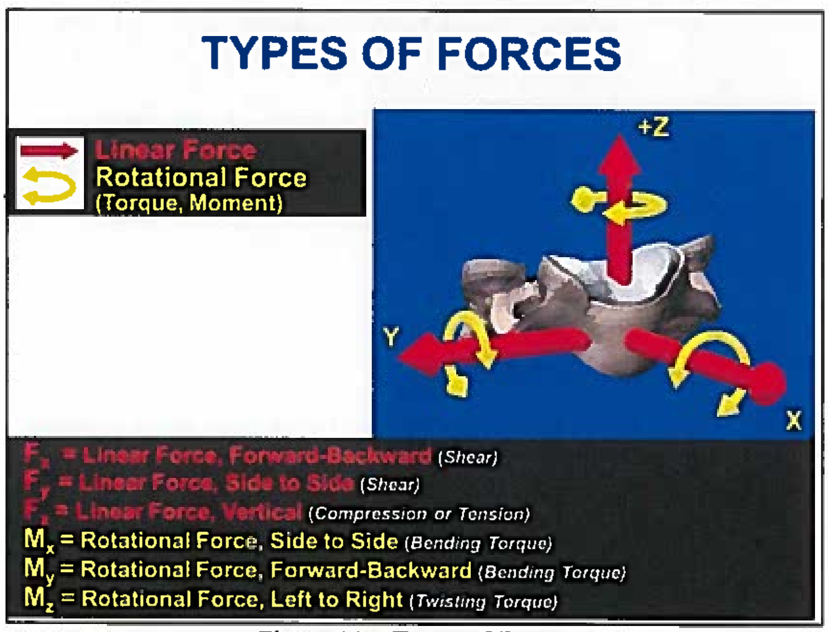

Figure 11 – Types of Forces

E-4.1Medical Records / Biomechanical Perspective:

A review of the medical records was performed to assess K[redacted] F[redacted]'s injury patterns. Figure 12 is a brief summary of the injuries as documented in her medical records. For a complete description of the injuries please see all medical records. For injury comparison purposes, Ms. Ashley Faust's (driver) medical summary is shown in Figure 13.

[redacted]

Figure 12 - Injury Pattern Analysis (Front Right Passenger)

[redacted]

Figure 13 – Injury Analysis, Ashley Faust (Driver)

According to NHTSA document (1996), the biomechanical brain injury parameters (HIC 36 and peak head acceleration) for 11-year-old [redacted], would be the same as an adult.

Klinich KD, et al. "Techniques for Developing Child Dummy Protection Reference Values" National Highway Traffic Safety Administration (NHTSA) Child Injury Protection Team, Docket No. 74-14, Notice 97, Item 069, October 1996

The major anatomical difference between children and adults is the proportion of the overall body weight versus head weight. The comparative illustration of the human skull at different ages is shown in Figure 14 (Burdi, et al, 1969). As can be seen the skull will reach 90% of its' adult size by the approximate age of 10 years. Even with general features of the head to be present, for children, the completion of growth does not occur until their 20's. The mechanical properties of biological tissues as modules of elasticity, ultimate strength and percentage of elongation vary with age; however, adult's characteristics are not necessarily stronger than children's. To appreciate the biomechanical properties as a function of age, one can examine the data published by Currey and Butler (1975). The modulus of elasticity versus age for femoral bone (Currey and Butler, 1975) is presented in Figure 15.

Burdi, A. R., et al, "Infants and Children in the Adult World of Automobile Safety Design: Pediatric and Anatomical Considerations for Design of Child Restraints", Journal Biomechanics, Vol. 2, pp 267-280, 1969

Currey, J.D. and G. Butler, "The Mechanical Properties of Bone Tissue in Children", J Bone Joint Surgery, Vol. 57A, No. 6, pp 810-814, 1975

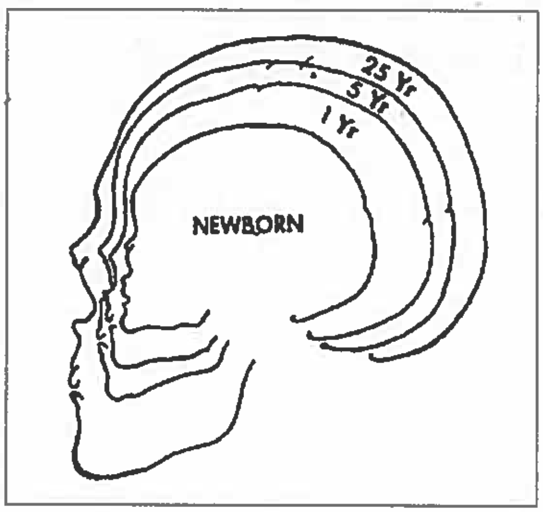

Figure 14 – Differences in Size and Shape for the Human Skull

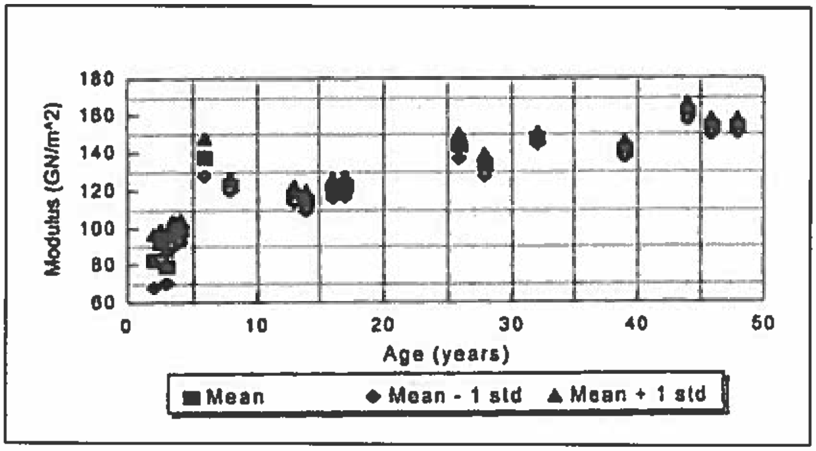

Figure 15 - Modulus of Elasticity vs Age for Children, Femoral Bone

Additional information regarding the anatomy of children versus adults was published by Sturtz (1980) and Chang and Reichert (1998).

> *Sturtz, G., "Biomechanical Data of Children", Society of Automotive Engineers, #801313*

> *Cheng, J.S. and K. W. Reichert, "Adult and Child- Head Anatomy", Frontiers in Head and Neck Trauma, IOS Press, 1998*

The biomechanical assessments of K[redacted] F[redacted]'s injuries are consistent with bodily trauma resulting from a combination of linear and angular forces/accelerations. As listed in the medical records (Materials Studied #4a-c) the cause of death includes, but is not limited to, severe head/brain injuries incurred when her head struck the interior components of the vehicle and/or the driver. Injuries consistent with head impact and subsequent brain death include the following:

1. Diffuse subarachnoid hemorrhage
2. Left subdural hemorrhage
3. Diffuse cerebral edema
4. Multiple facial fractures
    a. Left and right mandible fractures
    b. Zygomatic process
    c. Left maxillary sinus
    d. Left pterygoid plate
    e. Bilateral temporal bones
    f. Left inferior orbital rim
5. Bilateral temporal bone fracture
6. Pneumocephalus

Injuries corresponding to torso impact, most likely due to excessive excursion and contact with the interior structures of the vehicle include, but are not limited to:

1. Right internal carotid artery injury/occlusion
2. Grade I liver laceration
3. Hemoperitoneum (internal bleeding)
4. Multiple pulmonary contusions

The totality of the evidence indicates Ms. [redacted]'s fatal injuries are a result of the restraint systems failure; specifically the failure of the front airbag to deploy, and the seat belt's failure to keep her within the confines of her seat.

Comparison of the driver's injuries with the passenger's injuries was made. It must be noted the driver suffered several right-side head injuries, including but not limited to:

[redacted]

There are two (2) potential impact scenarios consistent with Ms. [redacted]'s diagnosed injuries. Specifically, Ms. [redacted]'s *left-sided* head injuries and Ms. Ashley Faust's *right-sided* head injuries are consistent with the occupants impacting one another and direct impact with the intruding interior components of the vehicle.

In comparison to the front passenger, the driver's survival space was severely compromised. Yet, the driver, Ms. Ashley Faust, survived the incident with AIS Level 3 (Serious) physical injuries. Both passengers experienced the same collision; however, Ms. Ashley Faust's restraint systems performed correctly; specifically, her front airbag deployed and her seat belt functioned properly.

E-4.2 Interior Measurements and Surrogate Fit

The interior of the exemplar vehicle was measured and photographed. The stiffness and friction characteristics of the rear passenger's seat were determined. The following tests were performed:

- Force deflection for front right passenger's backrest using test plunger
- Force deflection for front right passenger's headrest using an occipital plate
- Force deflection for front right passenger's seat cushion using test plunger
- Coefficient of friction

In the above-listed testing, the following equipment was used:

- Dillon Force Gauge BFG 2500N, Serial Number 05-0257-04, Certificate Number 516385
- Occipital Plate – Skull Cap, Machined, Part Number 78051-221; Skin, Cap Skull – Part Number 78051-229

The objective of the surrogate fit (Figure 16) was to relate geometrical dimensions of the 2012 Chevrolet Malibu to the height of Ms. Faust's 58 inches. The GEBOD (AL/WPAFB) computer program was used to generate the body description for Ms. Faust's anthropometry. The GEBOD output indicates the seated height of 30.55 inches. The selected surrogate GEBOD output had a seated height of 30.2 inches resulting in a 0.35 inch lesser seated height for the surrogate as Ms. [redacted]. Additionally, GEBOD output data set includes the body segments' geometric and mass properties and the joints' locations and range of motion characteristics that allows for detailed dimensional comparisons. Only a surrogate having similar underlying skeletal dimensions in comparison to Ms. Faust is of relevance in static geometrical fit. Primarily, surrogate height is used for analysis.

Figure 16 – Surrogate Fit in Exemplar Chevrolet Malibu

E-4.3 Subject Vehicle Interior Forensic Evidence
My inspection included:

- Examination of the seat belt system components for evidence of occupant usage which were created as occupant restraint forces were transferred onto the seat belt system.
- Inspected the seat belt anchorage points for occupant loading induced deformation
- Inspected the interior of the vehicle for evidence of occupant contact ("witness marks"), indicative of occupant kinematics during the crash.

According to the Oklahoma Traffic Collision Report, the CDR, and Ms. Faust's medical records (Materials Studied #1, #2, and #4a-c respectively) Ms. Faust was properly belted at the time of the incident. Marks consistent with belt loading were present (Figure 17) with polymer flow observed on the D-ring, cuts noted at approximately the 3 ½-inch mark and 41-inch mark, as measured from the outboard floor anchor respectively. Web abrasions were observed at approximately 13 – 22-inches from the outboard seat belt anchor and up to 10-inches from the D-ring.

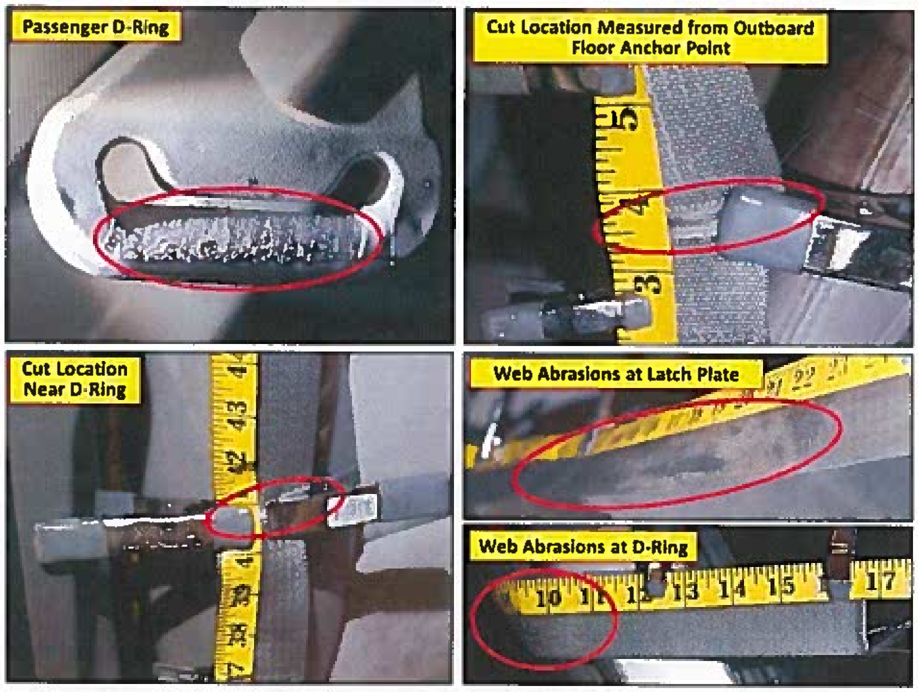

Figure 17 – Passenger Seatbelt Load Marks

Vehicle inspection indicated deployment of the driver's side front airbag but not the passenger side. Intrusion was noted to be >12 inches on the driver's side with steering wheel deformation. Passenger side survival space was relatively maintained with a rightward shift (towards passenger door) of the dash and instrument panel (Figure 18).

Figure 18 – Interior Vehicle Inspection

Conclusion: Ms. [redacted] was a properly seated and belted occupant at the time of the incident. However, due to the failure of the vehicle's restraint and safety systems to protect her, she suffered fatal head and abdominal injuries.

E-4.4 Human Body Kinematic / Kinetics

Prior to the impact on March 17, 2014, the 2012 Chevrolet Malibu and its occupants were moving at essentially the same speed with respect to the ground. Once the Chevrolet Malibu strikes the tree, the impact forces cause the vehicle to change speed, shape, and direction, while the occupants continue to travel at their pre-impact velocity. The difference in speed between the vehicle and the occupants create a movement of the occupants relative to the vehicle's structures. During the subject collision, the impact of the Chevrolet Malibu with the tree on the front driver's side of the vehicle caused the frontal structures to intrude inward into the driver's compartment. Obeying the laws of physics, Ms. Ashley and Ms. [redacted]'s bodies initially continued to move in the pre-impact direction.

Ms. [redacted] was the front right passenger involved in an impact which met the conditions for frontal airbag deployment. However, the airbag failed to deploy and the seat belt failed to restrain her within the safe confines of her seat.

To ensure that severe injuries and death are avoided in moderate to high Delta-V impacts, seat belts, seat contour padding, and airbags must work congruently as a safety system to keep the occupants restrained within their seats. The subject vehicle's seat belts are designed to work in combination with the airbag. The airbag system malfunctioned, causing the passenger's side airbag to not deploy. The load limiter introduced enough slack in the belt to allow shoulder slip out.

The point of impact to the 2012 Chevrolet was front left, with most of the energy being absorbed toward the driver's side. Since the human body tends to move toward the point of impact (POI), Ms. [redacted]'s body moved forward and to the left, allowing the shoulder belt to slide off the torso resulting in forward flexion over the lap belt. Webbing marks indicate there coul have been as much as 9.5-inches of load limiter deployment. From a biomechanical perspective, one can identify three primary mechanisms that contributed to Ms. Faust's injuries; (1) slip out from the shoulder belt (2) the excessive upper body flexion (3) direct body contact with the interior structures of the vehicle and/or the driver.

An example illustrating shoulder belt slip-out for conditions substantially similar to the subject event is NHTSA Test No. RD5910. As shown in Figure 19, the test was a frontal oblique offset collision at 90.1 kph (approx. 56 mph), PDOF of -15° (to the left) and 35% overlap (2013). Unlike the subject incident, the test conducted by NHTSA shows front right passenger airbag deployment and no excessive intrusion to the driver's side compartment.

> *Calspan Corporation Transportation Test Operations, Report Number R&D-CAL-13-004, "Moving Barrier to Vehicle Crash Test in Support of NHTSA's Frontal Oblique Offset Program Research Moving Deformable Barrier into Left Front of a 2013 Volvo XC60", NHTSA No: RD5910, November 11, 2013*

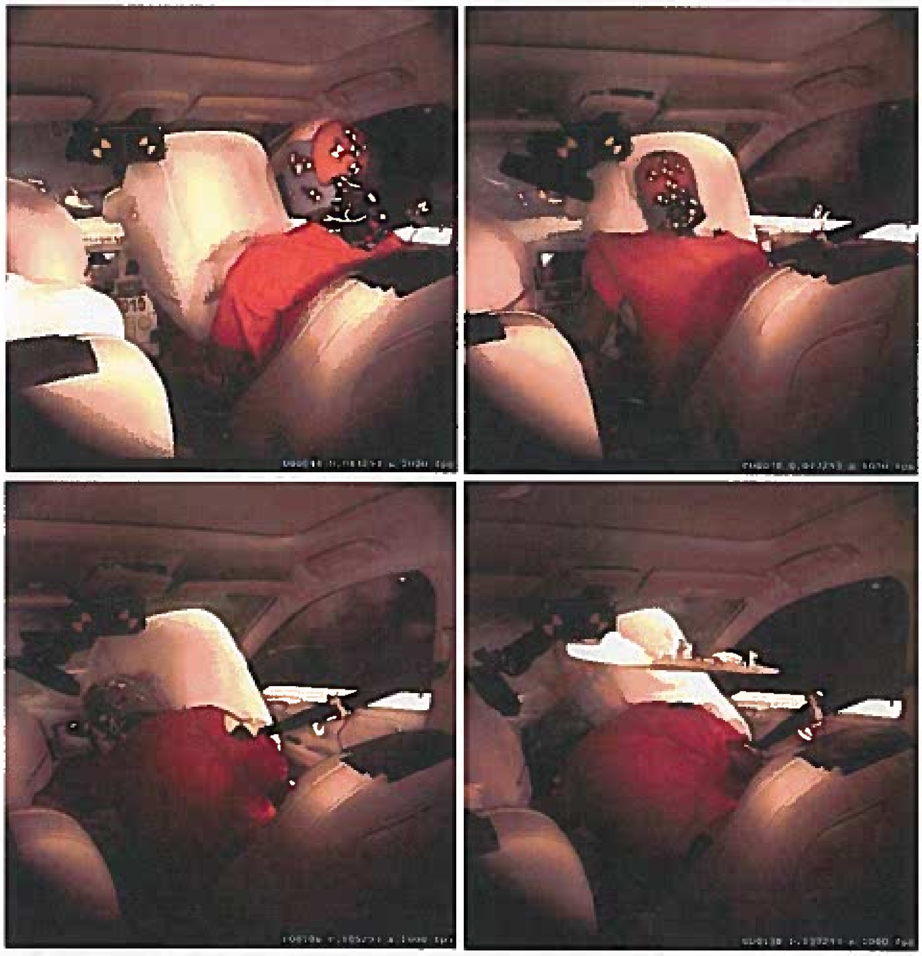

Figure 19 – Shoulder Belt Slip Out for Right Front Passenger, NHTSA Test No. RD5910

The lap belt portion of Ms. [redacted] [redacted]'s 3-point restraint system most likely provided resistance along the lower extremities of her body during the collision resulting in her abdominal injuries. If the load limiter on the seat fails to provide sufficient restraint, the upper torso, the legs, and pelvis are thrown against the lap belt, thus creating a fulcrum point along which stresses are magnified (Figure 20). This type of force can cause injuries within the soft tissues and organs of the abdomen (Murphy, 2015).

Murphy, D., M.D., (2015, June 25). "Car Accidents: Seat Belt Fulcrum Injury and the Cauda Equina Syndrome",https://chiro-trust.org/whiplash/car-accidents-seat-belt-fulcrum-injury-cauda-equina-syndrome/

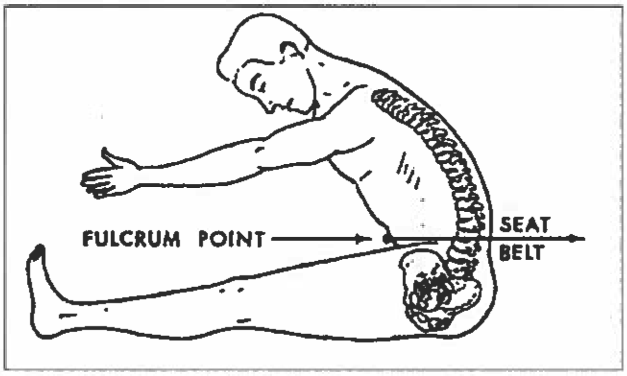

Figure 20 – Lap Belt Creating Fulcrum Point (reproduced from www.chiro-trust.org)

Since the front passenger's survival space was relatively maintained, (Figure 8 previously), and the driver (with properly functioning restraint systems) survived the incident, one can conclude Ms. [redacted] [redacted]'s injuries were the direct result of the airbag non-deployment and excessive forward excursion.

F. ALTERNATIVE DESIGN ANALYSIS

According to Mr. Hannemann's report, safer alternative designs would include, but are not limited to:

1. Safety Belt
   a. Load limiters with a stop.
   b. Utilize an adaptive load limiter.
   c. Utilize a higher force on the load limiter as was done for the 2008-2010 Chevrolet Malibu.
2. Seat Design
   a. Utilize the patented design by Hyundai that eliminates the need for a mat on the seat cushion and instead uses load sensors on the seat frame.
3. Occupant Classification System
   a. Utilize a design that uses load sensors on the seat which do not cause interference with the seat cushion or affect anti-submarining effectiveness.

Based on my education, training and experience as well as my knowledge of testing of these principles, I can state that these safer alternative design features would have resulted in less than fatal injuries for Ms. [redacted] [redacted]. A seat belt which utilized load limiters with a stop, adaptive load limiters or incorporating a seat belt with a higher force on the load limiter (5kN vs 2kN) would have kept Ms. [redacted] [redacted] within the safe confines of her seat. The subject collision met the criteria for the deployment of the front airbag. Sensors and OCS design alternatives would most likely have prevented the suppression of the front passenger airbag, providing a barrier between intruding vehicle structures and/or impact with the driver.

G. ***OPINIONS***

All of my opinions and conclusions throughout this report are given to a reasonable degree of engineering, biomechanical and scientific certainty.

1. **Ms. [redacted] [redacted] was a properly belted and seated front passenger in the 2012 Chevrolet Malibu on March 17, 2014.**
2. **The front passenger's survival space was relatively maintained.**
3. **The conditions in the subject incident for driver and passenger frontal airbag deployment were met.**
4. **Review of medical records indicates direct trauma to Ms. [redacted] [redacted]'s abdomen, resulting in multiple internal organ injuries and bleeding.**

5. **Review of medical records indicates direct trauma to the left side of Ms. K[redacted] F[redacted]'s head resulting in a massive skull fracture and brain death.**
6. **Three primary mechanisms that contributed to Ms. Faust's injuries were identified; (1) slip out from the shoulder belt (2) the excessive upper body flexion, and (3) direct body contact with the interior structures of the vehicle and/or the driver.**
7. **The driver, with properly functioning frontal airbags and restraint systems, survived the incident, even though her survival space was severely compromised.**
8. **With the safer alternative designs suggested by Mr. Hannemann, Ms. K[redacted] F[redacted]'s injuries most likely would not have been fatal.**
9. **Ms. K[redacted] F[redacted]'s injuries and subsequent death are directly related to the failure of the frontal airbag to deploy, and the failure of the seat belt to prevent excessive forward excursion.**
10. **Had Ms. K[redacted] F[redacted]'s safety and restraint systems functioned properly, she most likely have would have survived the incident, as the driver did.**

I reserve the right to amend this report, to modify, change and/or to alter my opinions predicated upon further discovery and upon receipt of any additional materials.

Sincerely yours,

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